Economics of Converting Military Waste to Fuel

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Conversion of Military Waste to Fuel

• Paradigm shift:
  – Treat waste as a resource
  – Transform into fuel,
    fuel into power
  – Logistics savings
  – Smaller footprint

• But:
  – Will it work?
  – What are its economics?
Waste to Fuel Technologies

• Many alternatives:
  – Pyrolysis
  – Air gasification
  – Supercritical fluid gasification
  – Aqueous-phase reforming
  – Liquid anode fuel cell
  – Biodegradation

• Outputs
  – Hydrogen, methane, propane, gasoline, distillates including JP-8
Waste to Fuel Process Using Fluid, Heat & Pressure

Waste → GRINDER → FLUIDIZER → PRESSURIZER

Heat, Pressure → SEPARATOR → Distillation

Fluid → Generator

Fuel
Defense Advanced Research Projects Agency (DARPA) Supporting 3 Approaches

- DARPA’s approaches:
  - Supercritical water depolymerization
  - Liquid anode fuel cell
  - Enzymatic biodegradation

- Project labeled “MISER”
  (Mobile Integrated Sustainable Energy Recovery)
Assessment of Miser Net Benefits

• Assume Miser unit transforms military waste into sufficient liquid fuel to fire a 5kW generator

• Estimate resource savings

• Estimate capital & O&M costs

• Calculate Net Present Value
  – Re-estimate under varying assumptions
MISER Benefits

- Avoided cost of waste disposal
- Avoided cost of waste transport
- Avoided cost of transport fuel
- Avoided personnel cost
- Value of fuel produced
Avoided Cost of Waste Disposal

\[ T \cdot p \cdot D \]

Where: 
\( T \) = total tons of waste
\( p \) = proportion processed by Miser
\( D \) = per ton disposal cost

• 258 lbs of mixed waste/day needed to fuel a 5 kW generator
  – (Miser assumed 70% efficient; 18.8 lbs mixed waste/gallon of fuel, 
    5 kW generator burns 13.7 gal/day)

• Estimated average disposal cost = $100/ton*

• Then avoided waste disposal cost for 5 kW generator = $13/day

*Source: Hughes Associates
Avoided Cost of Waste Transport

\[ = T*p*1/A*2M*Q \]

where: 
- \( A \) = number of tons of waste per truck 
- \( M \) = miles traveled to waste site 
- \( Q \) = per mile truck depreciation rate

• Assume 5-ton truck, MISER at front lines (2.8 tons/truck, 186 miles each way, $1.88/mile)

• Then avoided waste transport cost = $32/day

• (Allocates 100% cost of trip to waste disposal)
Avoided Cost of Fuel to Transport Waste

\[ = T \cdot p \cdot \frac{1}{A} \cdot \frac{2M}{1/G} \cdot V(o) \]

where:  
\[ G = \text{miles per gallon} \]
\[ V(o) = \text{cost of fuel at base camp} \]

• Assume 5-ton truck fueled at base of operations

\[ (G = 4.1 \text{ mpg}, V(o) = $13/\text{gal}^*) \]

• Avoided transport fuel cost = $54/day

*Source: Defense Science Board, “More Capable Warfighting Through Reduced Fuel Burden”
Avoided cost of personnel

\[ = N \times H \times h \]

where:  
\( N = \) Number of soldiers to dispose of waste  
\( H = \) Hours of time/soldier  
\( h = \) Hourly soldier compensation rate

- Assume 2 soldiers per truck, 30 mph truck speed, 1 hour to pick up & dispose of waste, $18.40/hour compensation rate
- Avoided personnel cost = $23/day
Fuel Value

\[ \text{Fuel Value} = 13.7 \times V(M) \]

where: \( V(M) = \text{cost/gal to deliver fuel M miles from base of operations} \)

\[ V(M) = V(o) + c \times M \]

where: \( c = \text{per gallon per mile cost of delivering fuel in a combat theater} \)

- Assume tactical truck delivery ($0.031/mile/gallon)
- Value of fuel at front lines = $255/day
Total Daily Estimated Savings from 5 kW-supporting MISER unit

<table>
<thead>
<tr>
<th>Item</th>
<th>Savings</th>
</tr>
</thead>
<tbody>
<tr>
<td>Waste disposal</td>
<td>$13/day</td>
</tr>
<tr>
<td>Waste transport</td>
<td>$32/day</td>
</tr>
<tr>
<td>Transport fuel</td>
<td>$54/day</td>
</tr>
<tr>
<td>Personnel</td>
<td>$23/day</td>
</tr>
<tr>
<td>Fuel Value</td>
<td>$255/day</td>
</tr>
<tr>
<td><strong>Total resource savings</strong></td>
<td><strong>$377/day</strong></td>
</tr>
</tbody>
</table>
Capital Cost of Miser

- Estimated capital cost of 5 kW-supporting Miser unit using pyrolysis process:
  - @ 10 units produced = $28K
  - @10,000 units produced = $18.7K

- Scale factor for other unit sizes:

  \[ X = Y_i \times (S/5)^n \quad i = 1,2 \]

  Where:  
  - \( X \) = estimated cost of Miser of size \( X \)
  - \( S \) = Miser unit size (10kW, 15kW, etc.)
  - \( n \) = engineering scale factor (.6-.8)
  - \( Y_1 \) = cost of 5kW Miser when 10 are produced
  - \( Y_2 \) = cost of 5kW Miser when 10,000 are produced
Key Base Case Assumptions
(theater of operations)

- Annual O&M costs are 10% of capital costs
- 15 year equipment lifetime
- 5% discount rate
- MISER operates 8 hours/day, 90 days/year
- Fuel value = $13/gallon at base of operations
### 5kW MISER Net Present Value (NPV) Under Alternative Assumptions (in theater)

<table>
<thead>
<tr>
<th>Assumption</th>
<th>NPV ($K)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1) Base case</td>
<td>57</td>
</tr>
<tr>
<td>2) 6% discount rate</td>
<td>52</td>
</tr>
<tr>
<td>3) 10 year lifetime</td>
<td>36</td>
</tr>
<tr>
<td>4) Fuel value only (no waste disposal savings)</td>
<td>21</td>
</tr>
<tr>
<td>5) Fuel $2.50/gal at base</td>
<td>15</td>
</tr>
<tr>
<td>6) Capital costs $50K</td>
<td>15</td>
</tr>
<tr>
<td>7) Combination of 3,6</td>
<td>(1)</td>
</tr>
</tbody>
</table>
Effect of Generator Scale on MISER NPV

![Bar chart showing the effect of generator scale on MISER NPV. The chart compares NPV for different generator sizes: Base case (5kW), 10 kW, and 15 kW. The NPV values are indicated on the y-axis, and the generator sizes are on the x-axis.]
Key Base Case Assumptions (domestic installation)

- MISER operates 20 hours/day, 360 days/year
- Fuel value = $2.50/gallon
- 15 year equipment lifetime
- 5% discount rate
- Annual O&M costs 10% of capital costs
<table>
<thead>
<tr>
<th>Assumption</th>
<th>NPV ($K)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1) Base case</td>
<td>85</td>
</tr>
<tr>
<td>2) 6% discount rate</td>
<td>77</td>
</tr>
<tr>
<td>3) 10 year lifetime</td>
<td>72</td>
</tr>
<tr>
<td>4) Fuel $1.50/gal at base</td>
<td>45</td>
</tr>
<tr>
<td>5) Capital cost = $50K</td>
<td>42</td>
</tr>
<tr>
<td>6) Operate 12 hours/day</td>
<td>29</td>
</tr>
<tr>
<td>7) Combination of 3, 4, 6</td>
<td>(22)</td>
</tr>
</tbody>
</table>
MISER NPV at an Installation within the US

Generator Size and Number Produced

NPV

0 20 40 60 80 100 120 140 160 180 200

5 kW unit - 10 produced
5 kW unit - 10,000 produced
10 kW unit - 10 produced
MISER Challenges

- Process efficiency
- Liquid v. gaseous fuels
- Standards for military equipment
- Cost
Conclusions

• If MISER can produce liquid fuels from mixed waste, it likely will be cost effective in overseas military use.

• If MISER produces only gaseous fuels, it likely will be better suited for stateside use, on military bases and elsewhere.

• If MISER output can feed a militarily practical fuel cell, its investment attractiveness will depend on the rate at which it can transform waste and its cost.

• Waste-to-fuel process efficiency could be improved through the use of readily convertible plastics in place of paper, fiberboard and wood packaging.